THE EFFECTS OF SCIENTIFIC LITERACY ON HIGH SCHOOL SCIENCE LEARNERS' ATTITUDES TOWARDS SOCIO-SCIENTIFIC ISSUES: THE CASE OF GENETICALLY MODIFIED ORGANISMS.

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Declaration

We declare that this research report is our own unassisted work, with all other text acknowledged and indicated in the references. The content of the study has not been submitted to any other publication or conference except ICESS.

The effects of scientific literacy on high school science learners' attitudes towards socio-scientific issues: the case of Genetically Modified Organisms.

Abstract

One of the fundamental goals of science education globally has been to develop citizens who are scientifically literate and capable of making informed decisions on Socio-Scientific Issues (SSI). This study investigated the relationship between scientific literacy and grade eleven science learners' attitudes towards SSIs, with a specific reference to the use of Genetically Modified Organisms (GMOs) in society. One hundred and four (104) grade eleven science learners from two Johannesburg township schools participated in the study. The study employed a quantitative approach using a survey design for data collection, in assessing the relationship between scientific literacy and learners' attitudes towards GMOs. Findings from the survey revealed a significant correlation between scientific literacy and leaners' attitudes towards the use of GMOs, with spearman's rho, $r\ (102) = .726,\ p < .001$. 80.7% of the learners indicated that they had little or no understanding about GMOs; another 84.6% had no understandings of the processes of gene modification while 77.9% of the learners had negative concerns about the use of GMOs. Independent sample t-tests were further used to compare groups. Results of independent sample t-test indicated no significant differences in the attitudes of the male and female learners towards GMOs $t\ (102) =-2.289\ p>.05= .743$. However, a significant difference was noted in learners' attitude towards GMOs between school A and B $t\ (102) = 7.840\ p<.001$. The implications of these findings are associated with low scientific literacy levels, the abstract nature of concepts related to genes, genetic inheritance, and the popular misconceptions, which learners hold about the use of GMOs. The knowledge gaps within the curriculum, which exist in the specific grade level, also account for some of the negative attitudes learners' showed towards GMOs. Higher GMO literacy, noted at school A, was associated with a science club at the school in which learners had regular debates about several SSIs, including cloning and gene modification. Recommendations for practice and future research are also proposed in this study.

Key words: Scientific literacy, Socio-Scientific Issues, Attitude, Genetically Modified Organisms (GMOs).

Introduction

One of the main goals of 21st century science education globally, has been to develop societies in which, citizens who are scientifically literate and can contribute in making informed personal, economic and social decisions (Department of Basic Education [DBE], 2011; European Commission (EC), 2007; National Research Council [NRC], 2012). Scientific literacy though extensive in its definitions, is defined as the ability of a person to engage with and make decisions about science related political, economic, social and cultural issues, using scientific ideas and knowledge (Hodson, 2008; Holbrook and Rannikmae, 2009; Kapelari, 2015). This implies that, for a person to be scientifically literate, he/she should be able to understand the nature of science (NOS), the ways in which scientific knowledge is derived (scientific inquiry) and the content knowledge of core science concepts. When acquired, scientific literacy becomes one of the key lenses through which people can engage with socio-scientific issues (SSIs). SSIs are societal issues and concerns, which have their origins in science (Tsai, 2017). They are also referred to as "controversial, socially relevant, real-world problems that are informed by science and often include an ethical component."(Sadler, Barab, & Scott, 2007, p. 14). Some examples of SSIs directly related to the advancements in science include, but are not limited to cloning, the Genetic modification of living organisms, surrogacy, evolution, global warming and many more. In the attempt to develop a sustainable future for science, it is critical for science learners to have the fundamental understandings of how these science advancements are attained and used in society for the good of all humanity. Also worth mentioning, is the fact that, SSIs have been known to influence policies and decisions on climate change, environmental sustainability and food manufacturing in many parts of the world (Kothamasi & Vermeylen, 2011). For instance, even though GMOs have been used to target world food sustainability, some nations pass policies forcing manufacturers to label them, or not even sell them at all (Vigani and Olper, 2013). Despite all the controversies surrounding GMOs, several benefits have been recorded. Some benefits of genetically modified plants include resistance to disease, the provision of a sustainable food source to accommodate the ever-increasing global population, lower food prices, longer shelf life, and improved taste and enhanced nutritional composition. For genetically modified microorganisms, advancements in vaccine production, medicine and agriculture have been registered as some of the benefits of GMOs (Reibero, Barone, & Behrens, 2016). Some disadvantages of using GMOs include, cross-pollination of modified genes to weeds, creating super weeds, which are also resistant to weedicides. GMOs have been implicated in the increasing rates of childhood food allergies and the transmission of anti-biotic properties from GMOs to humans causing drug resistant illnesses. In summary, not enough research has been done on GMOs to affirm the long-term effect they may have on other living organisms (Kılıc, Taber & Winterbottom, 2016).

With the rise in socio-scientific issues, the South African Curriculum and Assessment policy Statement (CAPS), emphasises in its specific aims, the need for science learners to be actively involved in addressing issues, which affect technology, health and the environment. For instance, the CAPS for physical sciences encourages that, learners use "science and technology effectively and critically showing responsibility towards the environment and the health of others" (DBE: Physical Sciences, 2011, p. 5). On the other hand, the CAPS for the Life Sciences supports this idea in its specific aim 3 which states that, learners should be able to understand "the applications of Life Sciences in everyday life", (DBE: Life Sciences, 2011, p. 13). Table 1 below shows the incorporation of biotechnology as a whole and GMOs within the CAPS curriculum subjects.

Table 1. The incorporation of biotechnology within CAPS curriculum subjects

Grade level	**Subject**	**Aspect of Biotechnology**
Grade eight (8)	Technology	Impact of technology Processing The positive impact of technology: many natural materials have been replaced in modern times by new or improved materials. Some new materials are environmentally friendly by being biodegradable.
Grade nine (9)	Technology	Processing Indigenous technology Preserving food (first two methods theoretically, 2.3 practically) 2.1. Storing grain 2.2. Pickling 2.3. Drying and/or salting
Grade ten (10)	Life Science	Investigate and collect information on one example of each of the following as it relates to plant and animal tissues: Stem cell research (current trends) Cloning Discuss ethics and legislation related to stem-cell research and cloning Describe the following as it relates to tissues: Traditional technology e.g. traditional medicines and healers Medical technology e.g. immunity, antibiotics, blood transfusion. List possible careers in biotechnology
Grade eleven (11)	Life Sciences	Use of drugs, e.g. antibiotics; effect on microorganisms, Use of microorganisms to produce medicines (insulin, antibiotics), Traditional technology to produce beer, wine, cheese.
Grade twelve (12)	Life Sciences	Genetic engineering: stem cell research, genetically modified organisms, biotechnology, cloning, Mention of Mitochondrial DNA: tracing genetic links, Paternity testing, and DNA finger printing (forensics).

From the table above, it can be noted that aspects of cloning are explored in grade ten and again emphasised in grade twelve, where the bulk of the genetic engineering component is taught within the Life Sciences curriculum. Despite the transformations in the national science curriculum targeted at developing learners who could participate in addressing ongoing societal challenges and controversies, research findings reveal that many learners exiting South African high schools are not scientifically literate enough to participate in the debate around SSIs (Lelloit, 2014; Webb, 2009). With this recognition of the gap in scientific literacy, the study aimed to ascertain the relationship between scientific literacy and learner attitudes towards GMOs. Targeted at attaining this aims the following objectives were enlisted,

- To assess grade eleven science learners' understandings about the use of GMOs.
- To evaluate the attitudes that learners' showed towards the use of GMOs.
- To correlate levels of understanding to learners' attitude towards the use of GMOs in society.

The following research questions were posed to guide the inquiry.

1. What levels of understandings do grade eleven science learners have on GMOs?
2. What attitudes do grade eleven sciences learners show towards the use of GMOs in society?
3. How does the knowledge about GMOs compare with learners' attitudes towards the use of GMOs?

The following hypotheses were stated prior to the inquiry.

Null Hypothesis (Ho): Science literacy has no effect on the attitude of grade 11 Life Sciences learners towards GMOs.

Alternative hypothesis (Ha): Scientific literacy has an effect on learners' attitudes towards the use of GMOs.

Literature Review and Theoretical framework

This review examines the main constructs within the study and a theoretical framework of what constitutes basic scientific literacy. We also discuss scientific literacy as one of the fundamental goals of science education, the use of GMOs, the shortfalls of traditional science approaches and how attitudes are constructed.

Scientific literacy in the science classroom in relation to Socio-scientific issues. (Case: GMOs)

Scientific literacy refers to a person's ability to use their knowledge of scientific concepts and ideas to make decisions concerning the material, environmental and technological world in which they live (Organisation for Economic and Cultural Development [OECD], 2013). These decisions should usually be evidenced-based and one should be able to communicate them. According to Norris and Phillips (2003), someone who is scientifically literate should be able to understand and articulate scientific language, in relation to the differences between observations and inferences, evidence and explanations as well as claims and authentic scientific results. Scientific literacy also involves possessing an adequate understanding of the relationship "science and technology has with our everyday life and the society in which we operate" (Marks & Eilks, 2009, p. 240). What this implies is that, scientific literacy constitutes one of the fundamental outcomes for science learning. The curriculum documents and education standards in many countries including South Africa advocate a science education targeted for the purpose of a scientifically literate citizenry (DBE, 2011; EC, 2007; NRC, 2012; NGSS, 2013). In the South African Revised National Curriculum Statements (RNCS) for Natural sciences (grades 1-9), it was envisaged that the purpose of the subject was mainly to promote scientific literacy (DoE, 2002). This implies that, the ability of learners to construct and apply scientific knowledge and understanding; to appreciate the relationships and responsibilities between science, society and the environment are some of the most desired outcomes for science learning (Hodson, 2008; Senler, 2015; Tsai, 2017). The CAPS curriculum mentions the Genetic modification of organisms in the grade 11 Life sciences in the fourth term, strand 3 when the topic of food security under environmental studies is treated (DBE: Life Sciences, 2011). A closer analysis of the CAPS documents does not reveal any emphasis on the importance of the ongoing debate around the genetic modification of food crops and other organisms in South Africa today. A follow up on the topic of genetically modified organisms continues in grade twelve Life sciences strand 1 term 2 under the topic genetics and inheritance. The curriculum gaps identified included, the lack of the relevant information of the extent to which issues on GMOs can be addressed in the science classroom and the abstract nature of the concepts of genes and genetic inheritance (Kılıc et al, 2016)

UNESCO Project 2000+ (as cited in Holbrook, 1998, p. 13), emphasised the societal dimension of scientific literacy and its potential to promote the science interest for students and subsequently be a motivational tool in science learning. Learners can also be afforded the opportunity to participate in debates around scientifically oriented social issues which affect people on a daily bases. Therefore, ideally school science programs should be able to incorporate teaching/learning material that will assist educators in making science teaching relevant to the addressing of socio-scientific issues. Largely SSI are usually very controversial and affect decision making at the levels of policy and economy on issues including, global warming, food security, cloning, climate change and many more. Being scientifically literate then becomes a tool, which can be used by young scientists to question the world around them and develop ways to solve social problems related to science (Kapelari, 2015).

The importance of science literacy, in the international and South African context.

The advantages of scientific literacy are numerous and without a doubt, it is an important goal in the teaching and learning of science. Within the parameters of school science, scientific literacy opens the minds of learners in understanding the nature of science and scientific processes (Bellová, Melicherčíková, & Tomčík, 2018). With this Knowledge about science, it becomes easier for learners to develop into citizens who ask scientific questions, investigate the natural world and make judgements on social issues rooted in science (NGSS, 2013; OECD, 2013). Scientific literacy also fosters learners' science competencies, which include "the capacities to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (OECD, 2013, p. 9). With all these benefits it become relevant for educators and researchers to assess the levels of learners' scientific literacy as an important outcome of education.

The most controversial debate which arose in the adaptability of science curriculum towards the promotion of the "science for all" campaign are linked to two essays which stood out when looking at contemporary science education and the challenges of teaching science in social contexts. In the quest for higher levels of scientific literacy in the USA, some authors like Osborne (2007) argued that, despite the fact that scientific literacy is a stated aim in the science curriculum, contemporary science education is primarily 'foundationalist' because it advocates educating for future scientists versus educating future citizens. The second essay by Roberts (2007) identified the continuing political and intellectual conflicts, which derived their history in science education. His primary question was, "Should the curriculum emphasize science subject matter itself, or should it emphasize science in everyday-life situations in which science plays a key role?"(Roberts, 2007, p. 758). With all of these questions, Science Education Standards (NRC, 2005, 2012) acknowledge the importance of using the sciences to help learners understand and participate in the debate around social issues. In the CAPS curriculum, there is every indication that the development of scientific literacy is a very important and crucial issue. However, these expectations seem to be only on paper and have not played their transformative role in science education at the classroom level (Christie, Butler & Potterton, 2007; Lelloit, 2014). This call for the inclusion of strategies which can assist learners as well as teachers to move away from content-based school science to science which will empower learners to be able to make decisions on socio-scientific issues, are needed (Fensham, 2008; Marks & Eilks, 2009) and engage in argumentation and critical reflections on issues of science and society (Tsai, 2017).

Genetically Modified Organisms (GMOs)

Genetically modified organisms (GMOs) are plants or animals in which the DNA have been modified without the use of any natural means of reproduction. Individual genes are transferred from the "source" organism into the DNA of the "target" organism. In the case of plants, the resulting crops carry certain traits such as resistance to insect damage or improved nutritional value (www.ecowatch.com). A typical example within the South African context was the case of "Futhi", a cow born in Brits Johannesburg South Africa in the year 2003, who came into existence through some genetic engineering processes. In the process of Futhi's conception, the nucleus of a cow's somatic cell was removed and introduced into the ovum or egg cells of the cow, such that the egg cell had a diploid number (double the amount) of chromosomes and behaved as a fertilized egg. The resultant cell from this cow, was then implanted into the uterus of another cow where it underwent the stages of embryonic development to give rise to an offspring similar to the other cow but with the ability to produce seventy-eight (78) litres of milk per day (Isaac, Chetty, Manganya, Mpondwana & White, 2013). In one study on how learners understood genetics and inheritance in rural schools, in South Africa, findings revealed that, learners between the ages of 15-16 years held many alternative conceptions of the concepts 'cells, genes, genetically modified organism' and 'cloning' (Sebitosi, 2007). Some learners believe that because certain foods had been modified, the gene modification also got into their bodies when they ate the food. All these misconceptions contribute to some of the negative attitudes learners have towards GMOs. One of the most popular misconceptions that was recorded in the South African study was coined with albinism. Some learners believed that, when an albino child is killed, another would be born immediately thereafter (Sebitosi, 2007).

Despite the fact that the issues around GMOs are social debates, popular with media and web-based content, the question of how much science learners really know about GMOs and how their attitudes towards GMOs are affected by their knowledge, remains quite a challenge.

Attitude

Attitude can be defined as "a positive or negative position towards a situation, an object or an action" (Turanlı, Türker, & Keçeli , 2008, p, 258). It is not a behaviour that is easy to observe, and may be hugely influenced by beliefs and cultural dispositions (Bakr & Ayinde, 2014). This implies that, attitude deals with how a person might react to a certain subject and how much they know about the subject to be able to react the way they do. A study by some researchers indicated that attitude may not change over time and has a strong relationship to the behaviour of a person. It can also be imparted to learners through teaching but can be altered by other social factors (Chin, Yang & Tuan, 2016; Tsai, 2017). In the science classroom for example, attitude usually plays a fundamental role in that, sciences present deep and complex concepts that are intertwined with the society and to a larger extent influence the way we live (Akıllı, 2008; Turanlı, et al., 2008). It is therefore, very necessary for learners to develop a positive attitude towards science in general and socio-scientific issues in particular. There are three components of attitude namely: (1) "the cognitive component which refers to the beliefs and knowledge of the objects, (2) the affective component which includes feelings about the use of the object and (3) the behavioural Component which pertains to the manner in which people act towards the object." (Turanli et al, 2008, p. 261). The implications therefore, of developing positive attitudes towards SSI are extensive and beneficial for developing analytical thinking, critical thinking and higher order process skills that are relevant for the transformation of the society and leaners' interest in science. One of the best way to build this positive attitude is through the inclusion of SSI as part of everyday science teaching and learning in schools.

The traditional science approach and the shortfalls for scientific literacy

Science was mostly perceived in the early-mid 20th century as a course for a selected few, which focused mainly on knowing the hard-core scientific content knowledge and building scientist rather than citizens. This approach resulted in science curricula around the world which were characterized by isolated facts detached from their scientific origins (De Vos, Bulte, & Pilot, 2002), with little or no orientation applicable to students' "lives and the society" (Holbrook, 2005, p. 15). One of the major deficiencies of traditional science programs is that most of them do not teach how science is linked to those issues that are relevant to students' life, environment, and role as citizens (Chin et al, 2016). This results to the induction of many learners into society who are unable to participate in the discussion surrounding socio-scientific issues and the implications these issues for society. (Avi, Ingo, & Bybee, 2011). In the 21st century, many science curricula around the world are under continuous scrutiny, as there is a great need for transformation in both the pedagogy and content of science subjects. In South Africa particularly, this transformation seems to be very slow as learners may generally have the science process skills, but lack the appropriate content knowledge in which these skills can be useful (Wolff &Mnguni, 2015,). Although the idea of linking the learning of science to societal issues is not new to science teaching (Solomon & Aikenhead, 1994), the implementation therefore, seems to be the problem in most developing counties.

The Research Methodology and Design

The research followed a quantitative research methodology, which was best suited for a correlation study. Quantitative research is a systematic inquiry process that deals with observation of phenomena using mathematical and statistical means (Creswell & Creswell, 2017). This approach usually emphasises objective measurements, statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating pre-existing statistical data using computational techniques (Babbie, 2010, Creswell, 2007; Crewell & Creswell, 2017). Hence, for the study, the researchers preferred this approach as it was best suited in answering the research questions and testing the stated hypotheses. A survey design was employed for the study, to gather data at a set time with the purpose of describing, identifying and comparing the attitudes, behaviours and characteristics of a population (Cresswell, 2007; Cohen, Manion & Morrison, 2007).Cross-sectional surveys more so are administered to one or more "samples one time only" (Fraenkel & Wallen, 2009, p. 343). Data was collected using an adapted questionnaire from an Arab study by Bakr & Ayinde, (2014) which included fourteen items. The questionnaires were administered to the leaners form the two Johannesburg township high schools, under test conditions and collected immediately after completion for analysis. The first tier of each question asked a question against a Likert scale, while the second tier asked the explanation for the responses provided.

Data collection and instrument.

Prior to the collection of the research data, all relevant ethical issues were addressed and the necessary permissions obtained from all stakeholders involved in the study. The primary data collection was be by means of a cross-sectional pen and paper survey as already mentioned. The instrument used was a fourteen-item two-tier questionnaire, which addressed learners' understandings about GMOs and the attitude towards the use of GMOs. Questions 1-7 interrogated learners' understandings of the concepts of GMO. In this study the scientific literacy of the learners where assessed as the "knowledge about GMOs" parameter. For instance, in the first tier of question 3, learners where asked what levels of understandings they had about the processes of gene modification. In the second tier, they were asked to enlist the processes, which were involved in the modification of genes. On the other hand, question 8-14, examined the attitude of learners, towards the use of GMOs in society. Three open-ended questions were included at the end of the questionnaire items for elaboration purposes, since they were not directly targeted at answering any of the research questions. The questionnaire, adapted from Bakr & Ayinde,

(2014) was piloted for readability and internal consistency, with thirty (30) grade eleven learners at a different school similar in characteristics as the participant school but not part of the research sample.

The Sample

A sample of 104 grade eleven science learners were randomly selected from two public Township schools in the Johannesburg area of South Africa. Participants included both boys and girls of ages between 16-19 years old. Township schools are located in the previously disadvantaged black communities. The two schools were slightly different in that, School A had more learning facilities for science learning, than school B. For example, school A had a library and two separate science laboratories for Physical and Life sciences, respectively. The learners at school A through the help of a science teachers started a science club which met every Wednesday and engaged with social debates, like abortion, gene modification, cloning, organ donation, issues around HIV and AIDS, among other aspects which had social implications though originated from innovations in science. School B on the other hand, was poorly resourced and like several township schools, did not have a library or a laboratory, and had been previously rated as a critically underperforming school in Mathematics and Science. Children who attended these schools had mostly working class parents and both schools were non-fee paying schools, funded by the Department of Basic Education.

Data Analysis

Descriptive and inferential statistics were employed for data analysis using IBM SPSS for windows version 25. Descriptive statistics were used to summarise the survey data while measures of correlation were calculated to investigate the relationship between attitude and scientific literacy. Primary correlations were obtain through spearman's correlation coefficient and group comparisons were effected with independent sample t-test. Findings, discussions and conclusions were derived from interpreting the figures and tables, obtained from the analysis, as presented in the result section below.

Reliability and Validity.

Validity was ensured throughout the various stages of the study. Some aspects that were used to ensure the validity at data collection stage included, avoiding dropout rates amongst respondents by administering questionnaires under test conditions. Using SPSS 25 statistical software, Cronbach's alpha which measures the test of good fitness, was calculated to assess the internal consistency of the questionnaire items and was recorded α=.72 for items soliciting understandings of GMO and α= .75 for the items on learners' attitudes respectively. Exploratory factor analysis was performed from the data of the pilot study to establish the constructs under investigation.

Results

This section reports the results of the statistical analysis of the data, with the primary descriptive data presented first, followed by the direct responses to the research questions.

Demographics

Table 2 below, shows the gender and age distribution of the participants in the study. 44.2% of the learners were males while 55.8% were female learners. A majority of the learners (81.7%) were between the ages of 17 and 18 while the remaining were outliers constituting 14.4% of 16 year olds and 3.8% of 19 year olds.

Table 2: Demographic information for study participants

What is your gender?

		Frequency	Percent (%)	Valid Percent	Cumulative Percent
Gender	Male	46	44.2	44.2	44.2
	Female	58	55.8	55.8	100.0
	Total	104	100.0	100.0	
How old are you?					
	Age Group (years)	Frequency	Percent (%)	Valid Percent (%)	Cumulative Percent (%)
	16	15	14.4	14.4	14.4
	17	56	53.8	53.8	68.3
	18	29	27.9	27.9	96.2
	19	4	3.8	3.8	100.0
	Total	104	100.0	100.0	

Variables

The variables of this study were twofold, with understandings about GMOs being the independent variable while attitudes towards GMOs constituted the dependent variable. The data from pilot of 30 learners was subjected to an exploratory factor analysis to establish the constructs within the questionnaire item. Extraction was done by principal component analysis, varimax rotation with Kaiser Normalisation. Values less than <. 3 were suppressed and two factors from the questionnaire items were loaded as represented on the table 3 below. Items on the knowledge about GMOs had a Cronbach's alpha α = .72, while the attitude factor had α = .75

Table 3: Factors loading

Questionnaire Items	**Factor 1 (Knowledge about GMOs)** **(α = .72)**	**Factor 2 (Attitudes towards the use of GMOs)** **(α = .75)**
Do you understand the processes of gene modification?	.836	
How often do you read food labels?	.761	
Would you find out more about GMOs?	.750	
Have you Heard about GMOs before?	.749	
What is your level of understanding about GMOs?	.688	
Do you believe human genes are modified/consumption?		.682
Are GMOs something you look out for?		.681
How did you learn about GMOs?		.648
Do you have any concerns about GMOs?		.558
What is your opinion on production and sale of GMOs?		.483

What levels of understandings do grade eleven science learners have about GMOs and what attitudes do they display towards the use of GMOs?

Table 4 below shows a summary of the descriptive statistics for the study, which described the levels of understandings learners had about GMOs and the general attitudes they showed towards the use of these GMOs.The descriptive frequency, percentage, mean and standard deviation of the learners' responses are captured in table 4. Apart from question 1, all questions had a five-point scale of answers. For easier reporting categories like "No understanding and little understanding" were merged.

Table 4: Descriptive statistics for each questionnaire item

Question	Response	Frequency	Percentage (%)	Mean	Standard deviation
Have you Heard about GMOs before?	No yes	65 39 104	62.5 37.5 100	.38	.486
what is your level of understandings do you have about GMOs	No understanding Little understanding Not sure Moderate understanding Total understanding	69 15 10 9 1	66.3 14.4 8.7 1.0 1	1.25	.785
processes during gene modification	No understanding Little understanding Not sure Moderate understanding Total understanding	58 30 8 4 4	55.8 28.8 7.6 3.8 3.8	1.63	.837
How did you learn about GMOs?	social media Family and friends Life sciences classroom Grade 9 NS Total	23 64 16 1 104	22.1 61.5 15.4 1 100	1.95	.644
Do you have any concerns about GMOs?	No concerns A little concern Neutral A lot of concerns Major concerns Total	5 15 20 61 3 104	4.8 14.4 19.2 58.7 2.9 100	3.40	.940
What is your opinion on production and sale of GMOs?	Strongly Disagree Disagree Neither disagree nor agree Agree strongly agree	70 23 8 2 1	67.3 22.1 7.6 2 1	1.47	.800
Do you believe human genes are modified on consumption of GMFs?	Strongly disagree Disagree Neither agree nor Disagree Agree Strongly agree	14 19 5 10 56 104	13.5 18.3 4.8 9.6 53.8 100.0	3.72	1.573
How often do you read food labels?	Never Rarely Sometimes Most of the time Always	9 22 6 21 46 104	8.7 21.2 5.8 20.2 44.2 100.0	3.70	1.434
Are GMOs something you look out for?	Never Rarely Sometimes Most of the time Always	85 8 9 1 1 104	81.7 7.6 8.7 1.0 1.0 100.0	1.30	.709
How often do you eat organic food?	Never Rarely Sometimes Most of the time Always	27 37 34 5 1 104	26.0 35.6 32.7 4.8 1.0 100.0	2.19	.915
Would you find out more about GMOs after this study?	No Yes	15 89 104	14.4 85.6 100.0	.86	.353

As seen on the above table, question 1, 2 and 3 examined whether learners have heard of GMOs, had understandings about them and the processes involved in gene modification. The responses given revealed that, more than half of the learners (62.5%) had not heard of GMOs before responding to this questionnaire. After combining the responses “no understanding and little understanding” a majority 80.7% and 84.6% of the learners had no understanding about GMOs nor the processes involved in the modification of genes respectively. Question 4 revealed that the few learners who had heard about GMOs had only done so through family and friends with only

15.5% who had done so from the Life Sciences classroom. Even though these learners did not understand much about the processes of gene modification, 79.6% of the learners indicated that, they had many concerns about GMOs while 89.4% indicated that they disagreed with the production and sales of GMOs.

These findings indicate that, despite the lack of understandings about the processes of gene modification during the production of GMOs, learners automatically displayed negative attitudes towards the consumption and sales of GMOs. The follow-up open-ended and explanatory questions revealed that the learners had not understood the concepts that were taught as they studied food engineering, but more emphatic was the idea that, the social dimensions of GMOs was never really discussed in the Life Sciences. In addition, learners revealed that their concerns were mostly related to the health issues associated with the use and consumption of GMOs, as gathered from here say and beliefs of people living in their communities. Another group of the learners indicated that human genes could be consequently modified from consuming and using GMOs, because they could see that children in their generation matured faster than in previous generations.

What is the relationship between GMO literacy and grade eleven learners' attitudes towards GMOs?

Table 5 below shows spearman's correlation between the knowledge factors about GMOs and the learners' attitudes towards the use of GMOs. The data was transformed within SPSS and all the items that were related to understandings and attitudes were combined to form two new variables (Attitudes towards GMOs and Understands about GMOs). The results indicated a significant positive relationship between learners' knowledge about GMOs and their attitude towards the use of GMOs. A spearman rho r (102) = .726, p < .001 was recorded. This result implies that the less learners knew about GMOs the more negative the attitude they portrayed towards it, while those who knew better had more positive attitudes towards the use of GMOs. We therefore reject the null hypothesis (H_{0}), which stated that; there is no relationship between the knowledge about GMOs and attitudes towards the use of GMOs and accept the alternative hypothesis (H_a), which states that there is a relationship between scientific literacy and learners' attitudes towards GMOs.

Table 5: Spearman's correlation for variables Understandings versus attitudes

			Attitudes towards GMOs	Understandings about GMOs
Spearman's rho	Attitudes towards GMOs	Correlation Coefficient	1.000	.726**
		Sig. (2-tailed)	.	.000
		N	104	104
	Understandings about GMOs	Correlation Coefficient	.726**	1.000
		Sig. (2-tailed)	.000	.
		N	104	104
**. Correlation is significant at the 0.001 level (2-tailed).				

The result shown in table 5 above indicates a strong positive correlation between understandings about and attitudes towards GMOs. This implies that learners who did not understand much about GMOs showed even more negative attitudes towards the use of GMOs while those who showed understandings, a more positive attitude. Overall, the attitude scores were very low indicating that learners already had social misconceptions about the use and consumption of GMOs.

Comparative analysis of groups using independent t-tests.

Table 6 below displays the findings from independent sample t-test that were conducted to establish the differences in the attitudes towards the use of GMOs for different groups. We compared the males, the females, and the two different schools (A and B).

Table 6: Independent samples t-test results for differences in attitudes amongst groups (Gender and Schools)

Groups	N	Mean	Std. Deviation	Std. Error Mean	t	p
Males	46	3.35	1.303	.192	-2.289	p> .05= .743
Females	58	3.98	1.481	.194		
School A	52	4.58	.977	.136	7.840	P < .001
School B	52	2.83	1.279	.177		

As seen on the table above, the mean attitude scores for males and females were (M= 3.35, S.D = 1.303) and (M = 3.98, S.D = 1.481), respectively. From the t-test results, this indicated that there was no statistically significant difference, t (102) = -2.289, p=.743, in male and female learners' attitudes towards the use of GMOs. On the other hand, when school A and B were compared, attitude scores showed a statistically significant difference in the attitude scores whereby, learners at school A showed more positive attitudes towards the use of GMOs (M= 4.58, S.D= .977) than learners in school B (M= 2.83, S.D=1.279) at t(102)= 7.84, p< .001. Explanations provided for the open-ended questions indicated that the learners at school A were engaged in a science club at school were they spent quality after school time in scientific argumentation on socio-scientific controversies.

Discussions

The findings of this study tally with those of previous studies such as Bakr & Ayinde (2014), Kılıc et al, (2016) and Hess, Lagerkvist, Redekop, & Pakseresht, (2016), which reveal that learners as well as consumers have un-grounded pre-conceptions about the use of GMOs. It is also clear from these findings that, pre-conceptions formulated in the minds of learners are mostly based on hearsay and popular belief rather than the levels of understandings they have acquired on the subject of GMOs (Ribeiro, et al, 2016). These attributes explain the reason for why majority of the learners showed negative attitude towards the use of GMOs and predicts the hard work ahead for science teachers in identifying and dealing with learner misconceptions about SSIs like GMOs and their use in society. Findings of a meta-analysis by Hess et al. (2016) also indicated that, "respondents on average react more strongly with negative attitudes to potential risks from biotechnology, than with positive attitudes to potential benefits" (p. 729).

Contrary to these findings some studies like, Meerah, Harail & Halim, (2012) which investigated form four Malasian students of the same age group, on the understandings of biotechnology revealed that, learners to had comprehensive understandings of biotechnology processes and hence showed positive attitudes "towards biotechnology and its applications" (Meerah et al, 2012, p. 161). In the USA and other European countries, scientists largely considered genetically modified products as safe (Pew Research Centre, 2015). To this effect the European Commission (2010), upon evaluation of more than 130 research projects from a period of over 25 years, involving more than 500 independent scientific teams, concluded that GM food production cannot be considered more hazardous than conventional plant breeding technologies (EC, 2010). Recent years have, however, witnessed a number of controversies among which was the highly publicized study by Séralini, Clair, Mesnage, Gress, Defarge & Malatesta (2014), who reported that, herbicide resistant GM corn and associated herbicides can lead to long-term toxic effects and even tumour formation in rats.

In this South African study, learners showed little or no understanding of GMOs and the processes that were involved in gene modification. This lack of understanding revealed a knowledge gap within the Life sciences component on how GMOs should be taught progressively from one grade to the other. Even though bits about biotechnology cuts across every grade from grade eight to twelve, the abstract nature of the concepts of genetics, DNA and RNA replication, inheritance, coding, mitosis and meiosis pose a threat to learners' conceptualisation of the scientific processes involved in GMO production.

Recommendations

For educator and teaching practitioners we recommend a bridge of the knowledge gaps on gene concepts and their broader implications for society, with argumentation and social debates as proposed by Tsai (2017). We also advocate that the concepts related to the use of GMOs should be contextualised taught in more authentic spaces, such as factories and laboratories, so as to enhance conceptual understandings for learners. In addition, schools can introduce other extra-curricular spaces for learners to engage in argumentation on socio-scientific issues, which may enhance scientific literacy. Examples of such spaces include science clubs, science debate forums and online blogs.

For policy maker such as curriculum developers and advisors we recommend that a linking knowledge strand be added in grade eleven to consolidate the knowledge acquired from grade nine in order to enhance the fundamental understandings about genetic engineering processes prior to grade twelve.

For research, we recommend a larger scale study on the relationship between scientific literacy and learners' attitudes towards GMOs, within the South African context, as it is characterised by a diversity of differently resourced school types and other socio-economic factors.

Conclusions

In conclusion we recognise the the benefits and dangers of genetic engineering and other applications of biotechnology in the world today. The affordances of stem cell technology in modern medicine, the cultivation of more weather tolerant, disease resistant, and more nutritive food crops are but a few of the benefits of genetic engineering. On the other hand, there are unknown health and environmental consequences that can occur from consumption of foods, medicines and microbes that have been genetically modified. Whatever the social controversies that may emerge with these new technologies, it is important for science learners who constitute the researchers of tomorrow to have informed understandings of the scientific processes that go into the manufacturing of these GMOs and the conceptual understandings of how genes are manipulated. With this increase in conceptual understandings, learners' will be able to further investigate controversies as they matriculate into various Science Technology, Engineering and Mathematics (STEM) career pathways at the tertiary level and Life beyond.

Acknowledgments

We sincerely thank the DAAD-NRF joint in-country scholarship, which supported the publication of this research project.

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